Physiological Conditions Degrading Night Vision and Visual Illusions Caused by Darkness

The definition of night found in Title 14 Code of Federal Regulations (14 CFR) part 1: “Night means the time between the end of evening civil twilight and the beginning of morning civil twilight, as published in the American Air Almanac, converted to local time.”

The Human Eye

There are two kinds of light-sensitive cells in the eyes: rods and cones. The cones are responsible for all color vision. Cones are present throughout the retina, but are concentrated toward the center of the field of vision at the back of the retina. There is a small pit called the fovea where almost all the light sensing cells are cones. This is the area where most “looking” occurs (the center of the visual field where detail, color sensitivity, and resolution are highest).

While the cones and their associated nerves are well suited to detecting fine detail and color in high light levels, the rods are better able to detect movement and provide vision in dim light. The rods are unable to discern color but are very sensitive at low-light levels. The trouble with rods is that a large amount of light overwhelms them, and they take longer to “reset” and adapt to the dark again. There are so many cones in the fovea that are at the very center of the visual field but virtually have no rods at all. So in low light, the middle of the visual field is not very sensitive, but farther from the fovea, the rods are more numerous and provide the major portion of night vision.

Night Blind Spot

It is estimated that once fully adapted to darkness, the rods are 10,000 times more sensitive to light than the cones, making them the primary receptors for night vision. Since the cones are concentrated near the fovea, the rods are also responsible for much of the peripheral vision. The concentration of cones in the fovea can make a night blind spot in the center of the field of vision. To see an object clearly at night, the pilot must expose the rods to the image. This can be done by looking 5° to 10° off center of the object to be seen. This can be tried in a dim light in a darkened room. When looking directly at the light, it dims or disappears altogether. When looking slightly off center, it becomes clearer and brighter.

When looking directly at an object, the image is focused mainly on the fovea, where detail is best seen. At night, the ability to see an object in the center of the visual field is reduced as the cones lose much of their sensitivity and the rods become more sensitive. Looking off center can help compensate for this night blind spot. Along with the loss of sharpness (acuity) and color at night, depth perception and judgment of size may be lost.

Dark Adaptation

Dark adaptation is the adjustment of the human eye to a dark environment. That adjustment takes longer depending on the amount of light in the environment that a person has just left. Moving from a bright room into a dark one takes longer than moving from a dim room and going into a dark one.

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While the cones adapt rapidly to changes in light intensities, the rods take much longer. Walking from bright sunlight into a dark movie theater is an example of this dark adaptation period experience. The rods can take approximately 30 minutes to fully adapt to darkness. A bright light, however, can completely destroy night adaptation, leaving night vision severely compromised while the adaptation process is repeated.

Vision Types

There are three types of vision: photopic, mesopic, and scotopic. Each type functions under different sensory stimuli or ambient light conditions.

Photopic Vision:
Photopic vision provides the capability for seeing color and resolving fine detail (20/20 or better), but it functions only in good illumination. Photopic vision is experienced during daylight or when a high level of artificial illumination exists. The cones concentrated in the fovea centralis of the eye are primarily responsible for vision in bright light.

Mesopic Vision:
Mesopic vision is achieved by a combination of rods and cones and is experienced at dawn, dusk, and during full moonlight. Visual acuity steadily decreases as available light decreases and color perception changes because the cones become less effective. Mesopic viewing period is considered the most dangerous period for viewing. As cone sensitivity decreases, pilots should use off-center vision and proper scanning techniques to detect objects during low-light levels.

Scotopic Vision:
Scotopic vision is experienced under low-light levels and the cones become ineffective, resulting in poor resolution of detail. When using scotopic vision, color perception is lost and a night blind spot in the central field of view appears at low light levels when the cone-cell sensitivity is lost.

Central Blind Spot
The area where the optic nerve connects to the retina in the back of each eye is known as the optic disk. There is a total absence of cones and rods in this area, and consequently, each eye is completely blind in this spot.

Night Vision Illusions

Visual illusions result from the absence of visual references or the alteration of visual references, which modify the pilot's perception of his or her position (in terms of height, distance, and/or intercept angle relative to the landing area. Visual illusions can affect the pilot's situational awareness, particularly when landing. Visual illusions can induce pilot inputs (corrections) that cause the aircraft to deviate from the vertical or horizontal flight path.

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Be aware of the surrounding terrain and man-made obstacles in the flight path. At night, an unlighted hillside between a lighted area and the landing/takeoff area may prevent the flight crew from correctly perceiving the rising terrain.

There are many different types of visual illusions that commonly occur at night. Anticipating and maintaining awareness of them is usually the best way to avoid them.

Autokinesis
Autokinesis is caused by staring at a single point of light against a dark background for more than a few seconds. After a few moments, the light appears to move on its own. Apparent movement of the light source will begin in about 8 to 10 seconds. To prevent this illusion, focus the eyes on objects at varying distances and avoid fixating on one source of light. This illusion can be eliminated or reduced by visual scanning, by increasing the number of lights, or by varying the light intensity. The most important of the three solutions is visual scanning. A light or lights should not be stared at for more than 10 seconds.

Size-Distance Illusion
This illusion results from viewing a source of light that is increasing or decreasing in luminance (brightness). Pilots may interpret the light as approaching or retreating.

Fascination (Fixation)
This illusion occurs when pilots ignore orientation cues and fix their attention on a goal or an object. At night, this can be especially dangerous because aircraft ground-closure rates are difficult to determine, and there may be minimal time to correct the situation.

Night Landing Illusions
Landing illusions occur in many forms. Above featureless terrain at night, there is a natural tendency to fly a lower than-normal approach. Elements that cause any type of visual obscurities, such as rain, haze, or a dark landing environment, can also cause low approaches. Bright lights, steep surrounding terrain, and a wide runway can produce the illusion of being too low with a tendency to fly a higher-than normal approach.

Prior to flying at night, it is best to learn and know the challenges of the area in which you are flying in. Study the area and know how to navigate your way through areas that may pose a problem at night.